In-Situ Characterization of Cloud Condensation Nuclei, Interstitial, and Background Particles

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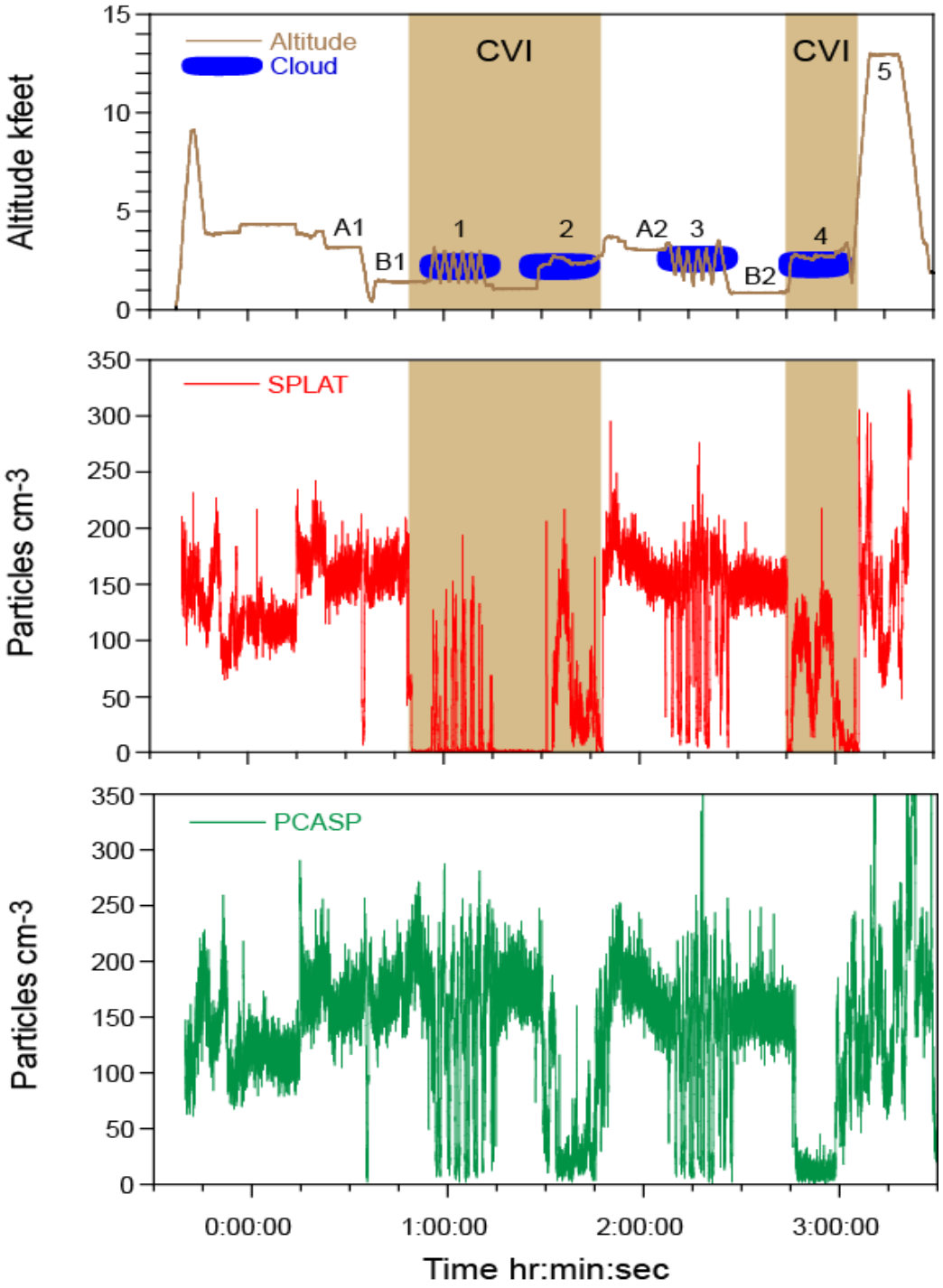
SPLAT II - ISDAC Data

- In April 2008 SPLAT II participated in 27 flights (>100 hours) of the Indirect and Semi-Direct Aerosol Campaign (*ISDAC*). It characterized
  - ✓ Size and internal composition of individual particles
  - ✓ Aerosol number concentrations (>100 nm)
  - ✓ Size distributions (d_{va})
  - ✓ Densities of particles with different compositions
  - ✓ Aerosol asphericity
- Sampling rate: sized up to 2000 p/sec, 20-50 of which are also chemically characterized
- ~10^7 particles were sized and over 3 million of them chemically characterized

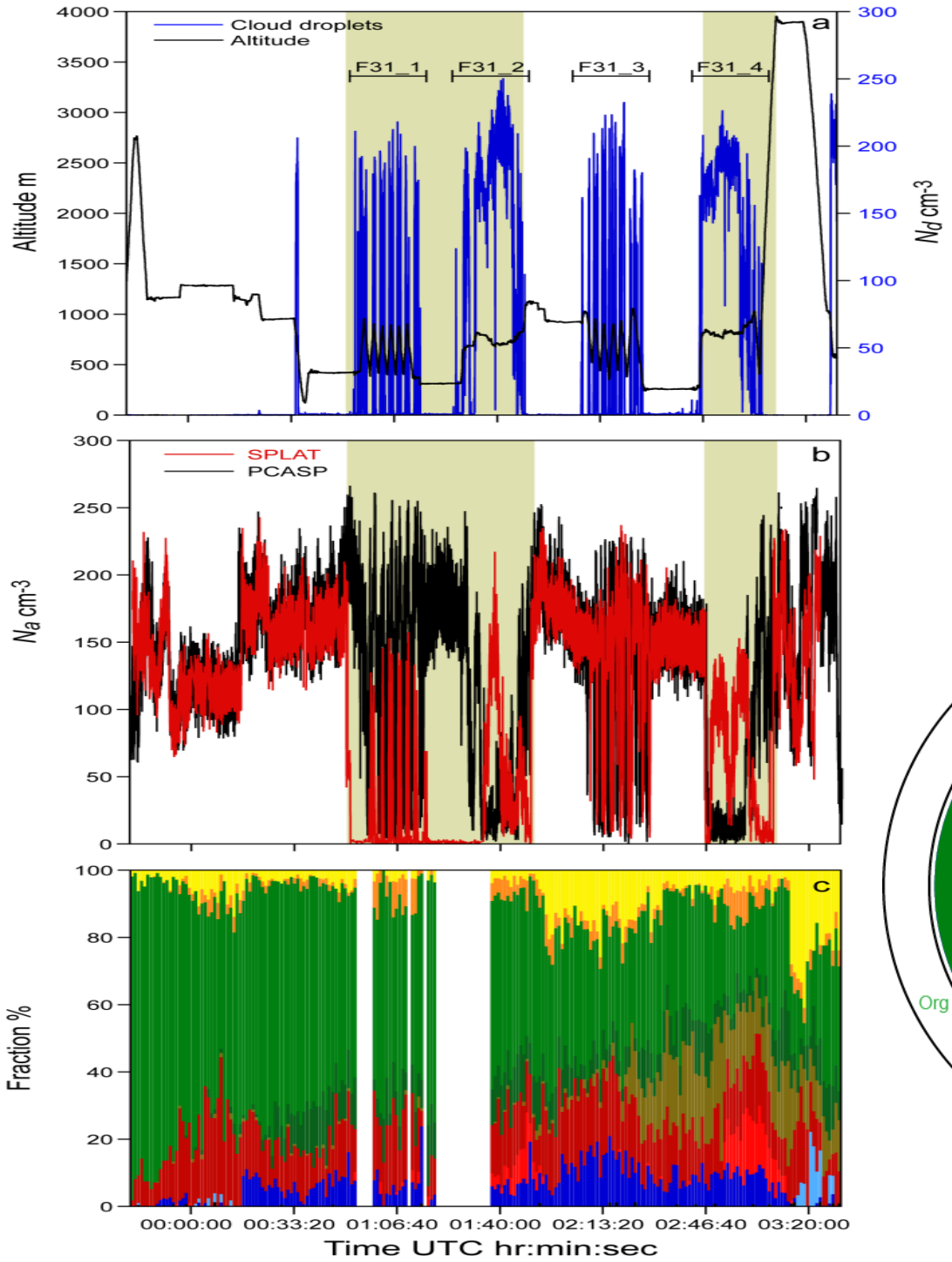
- SPLAT II was sampling particles alternately through the aerosol inlet, to characterize the composition and size of the overall aerosol population, and through the CVI inlet to characterize the composition and size of particles that served as CCN and IN
- Focus: CCN activity of aerosols characterized during clean and highly polluted days **and** their representation in the models



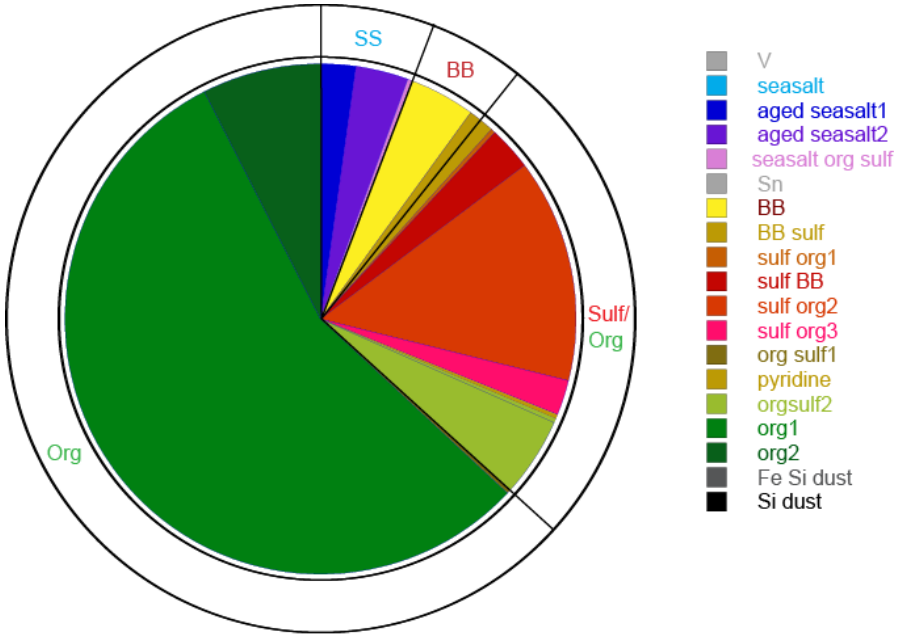
Clean Case, Warm Cloud (04/26/08, F31)

- N_a < 250 cm^{-3}
- A single-layer stratocumulus was encountered and characterized over the ocean near Barrow
- Four in-cloud characterization segments (Segments 1, 2, 4 provide data on CCN, and 3 can be used to find out which particles do not get activated)
- Segments A1, A2, B1, B2 are used to get information about particles above and below the cloud.
- Segment 5 provides a view of particles at higher altitudes.

F31: Clean Case, Warm Cloud

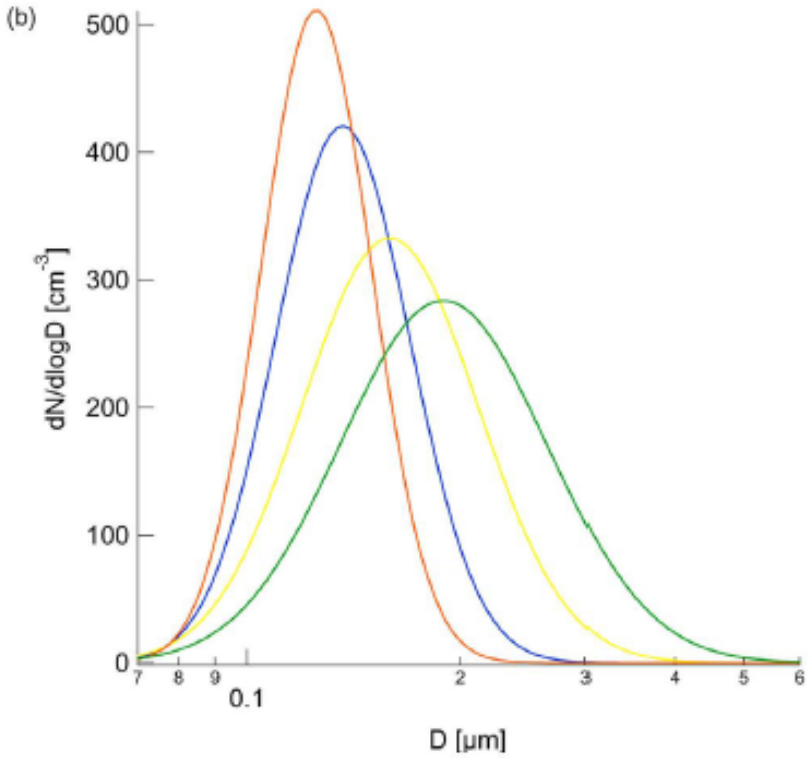


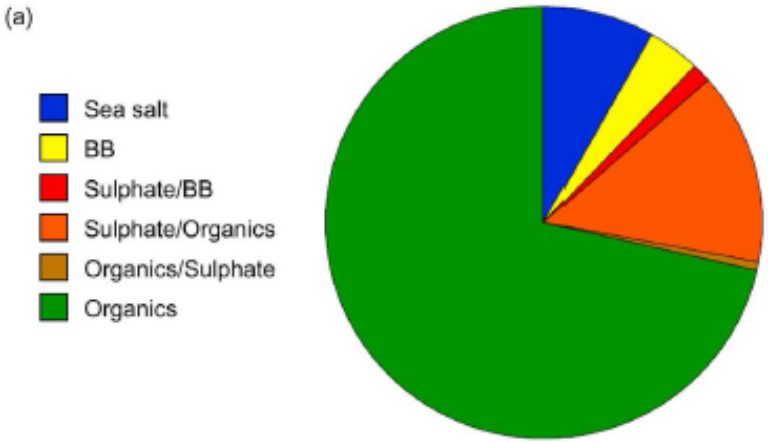
Particles were composed of organics and organics mixed with sulfates, biomass-burning (BB) particles, fresh and processed sea salt, and a small number of soot and mineral dust particles.



all data

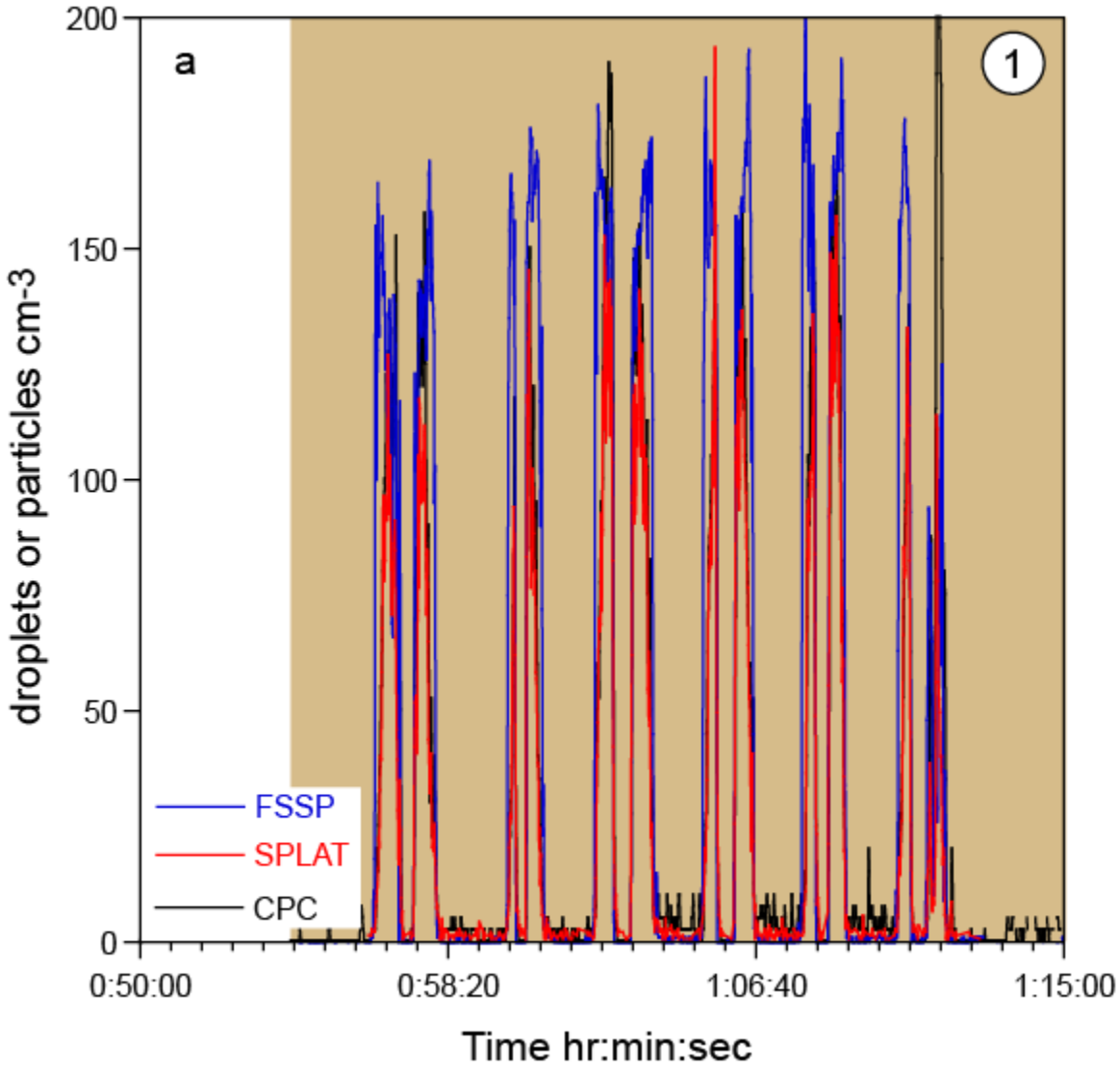
F31: Chemically-resolved Size Distributions





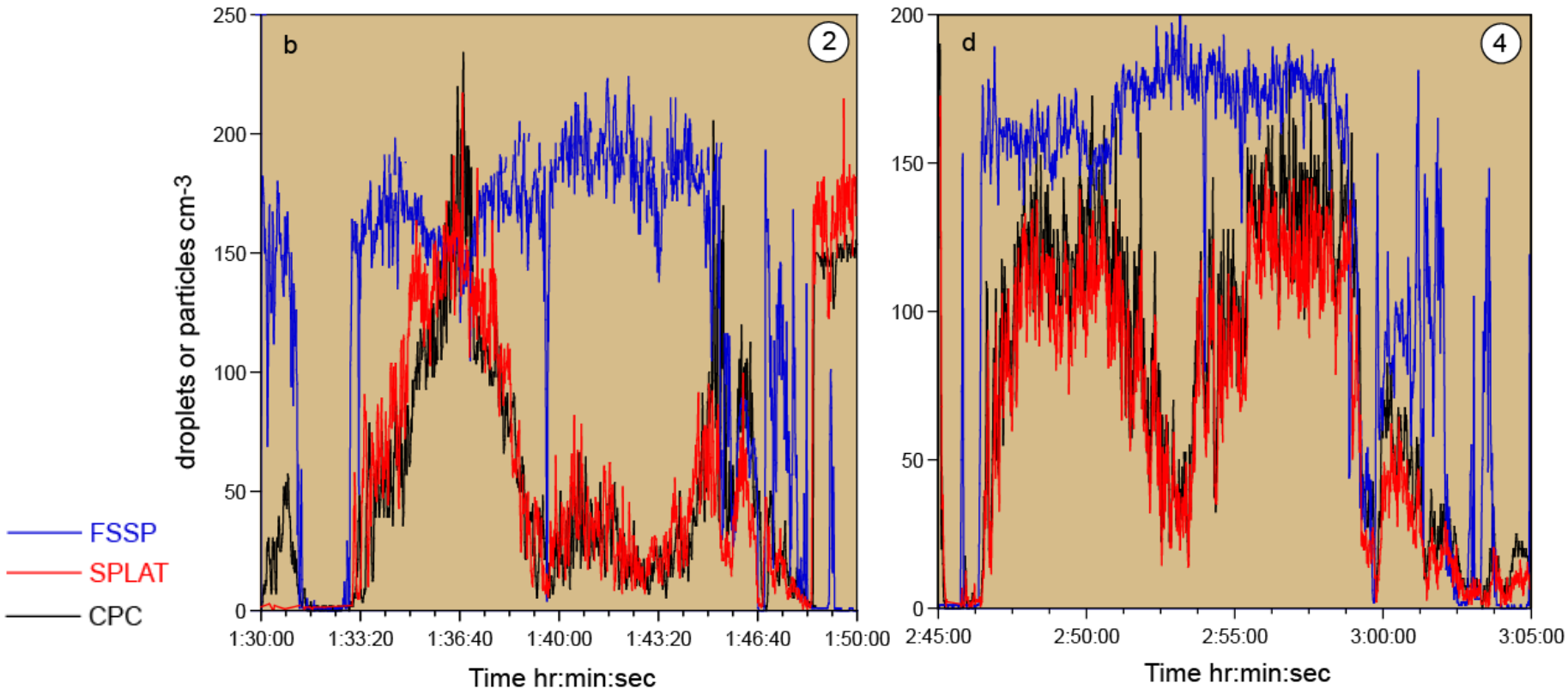
A slightly simpler representation of below cloud particle compositions and chemically resolved size distributions as measured by SPLAT

F31: Clean Case, Warm Cloud. Sampling Residuals



- Segment 1 involved cloud characterization by purposing through the cloud and sampling through the CVI
- The number of particles detected by SPLAT is in perfect correlation with the FSSP counts.
- Counts by CPC and SPLAT are nearly in perfect agreement
- ✓ Conclusion: Cloud residuals are larger than 100 nm

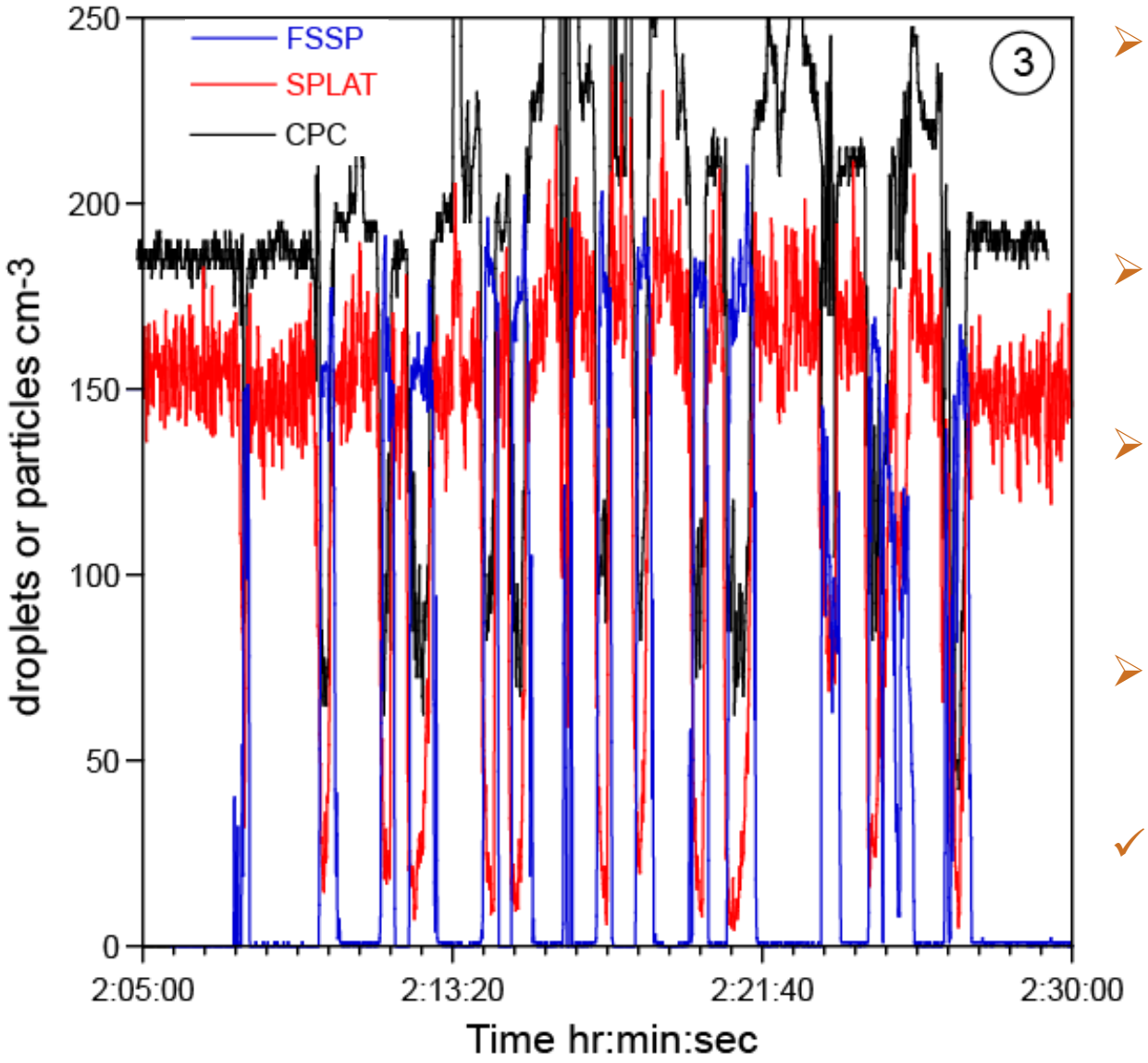
F31: Clean Case, Warm Cloud. Sampling Residuals



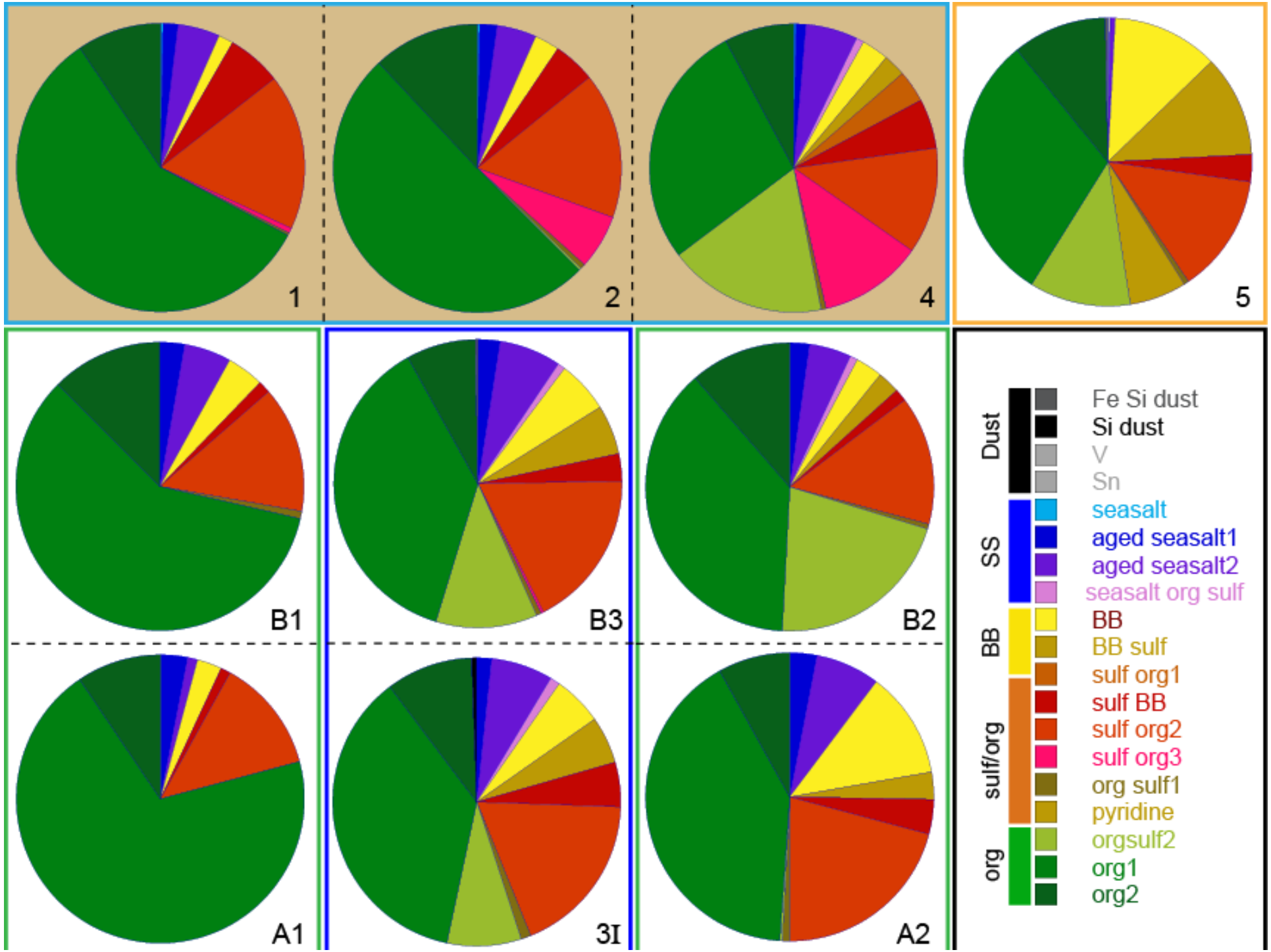
Segments 2&4 involved cloud characterization at constant altitude and sampling through the CVI

- The number of particles detected by SPLAT is **not** correlated with the FSSP count
  - ✓ Conclusion: cloud droplets sizes varied and a significant fraction was not transmitted by the CVI
- SPLAT detected the same number of particles as the CPC
  - ✓ Conclusion: Cloud residuals are larger than 100 nm

F31: Clean Case, Warm Cloud.



- Segment 3, cloud characterization by purposing and sampling through **aerosol inlet**
- Numbers of detected particles by SPLAT and FSSP are anti-correlated
- In this configuration SPLAT detects and characterizes the size and compositions of **interstitial** particles
- In the cloud, the CPC detects ~4 times as many particles as SPLAT
- ✓ Conclusion: 80% of interstitial particles are smaller than 100 nm


1
2
4
5
B1
B3
B2
A1
3I
A2
Dust
SS
BB
sulf/org
org
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aged seasalt2
seasalt org sulf
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sulf org3
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pyridine
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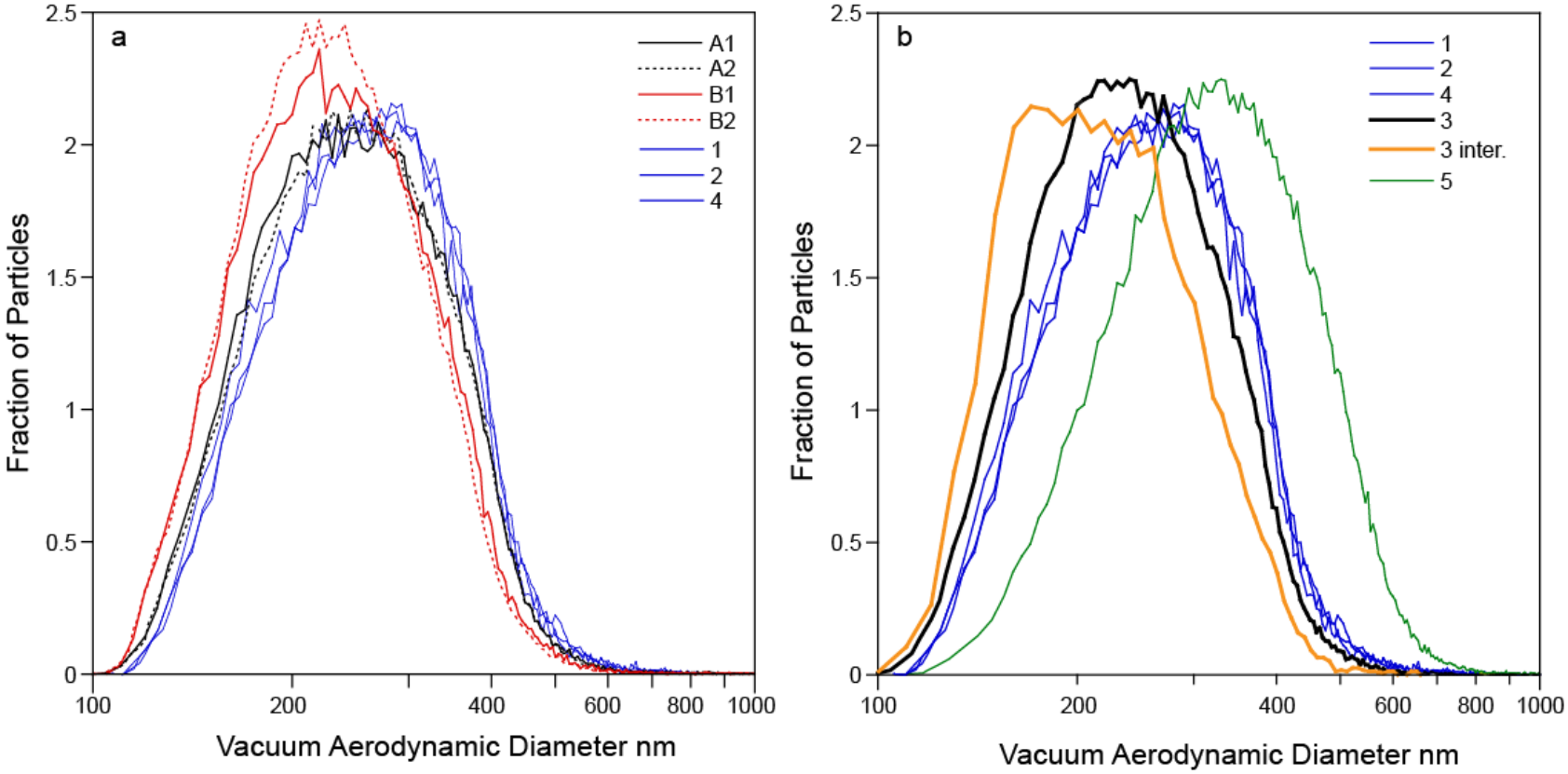
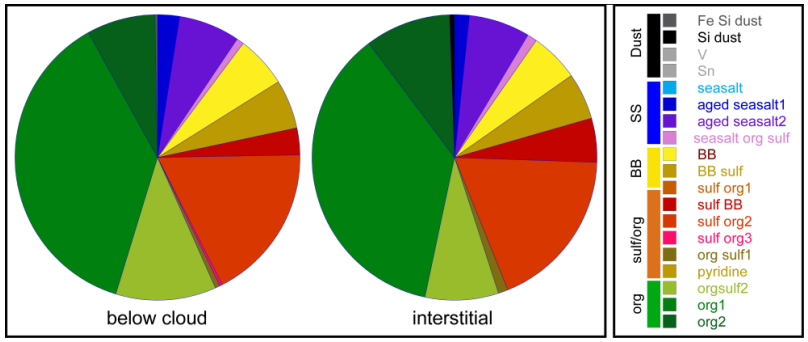
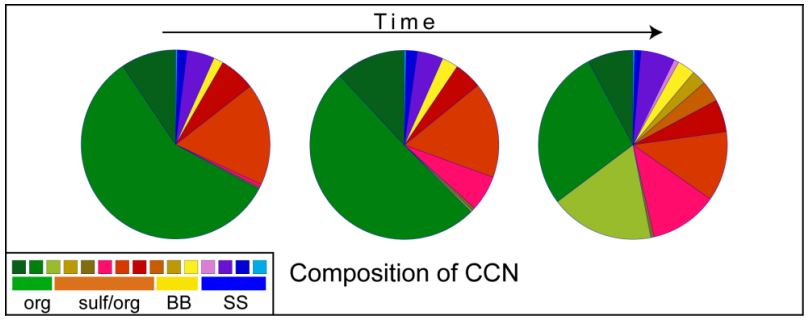
F31: Clean Case, Warm Cloud



Vacuum aerodynamic size distributions of sampled particles above cloud (black), below cloud (red), in-cloud through the CVI (blue), in-cloud interstitial particles (orange), at high altitude, segment 5 (green)

F31: Clean Case, Warm Cloud. Conclusions.





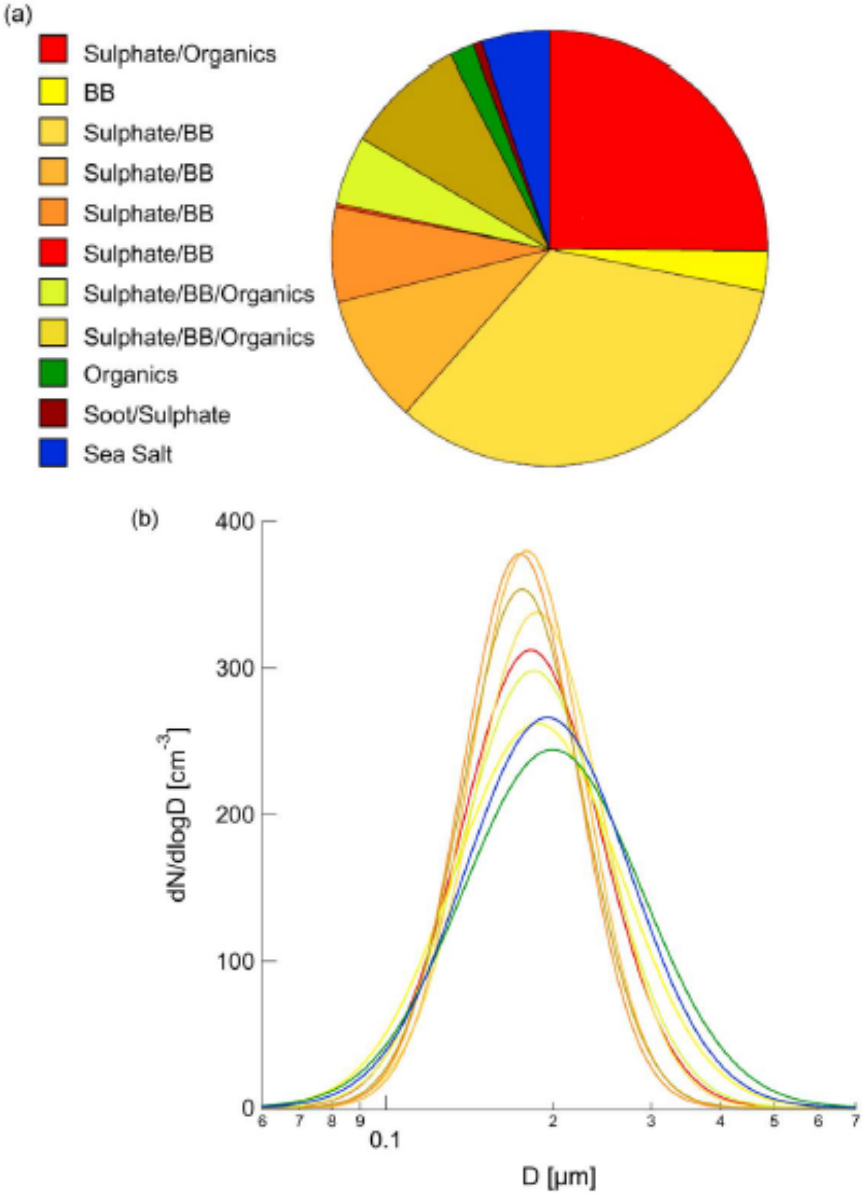
Zelenyuk A, *et al.* **(2010).** "In Situ Characterization of Cloud Condensation Nuclei, Interstitial, and Background Particles Using the Single Particle Mass Spectrometer, SPLAT II." *Anal. Chem.* 82:7943-7951.Special issue "Atmospheric Analysis as Related to Climate Change".

- ~95% of particles larger than 100 nm act as CCN
- 80% of interstitial particles are smaller than 100 nm
- Cloud droplet residuals have nearly the same composition as interstitial particles, having only ~6% more sulfate. (Dust particles do not activate)
- The sulfate content of cloud droplet residuals increased with time due to in-cloud droplet processing
- ✓ Conclusion: Particle size is the controlling factor in determining aerosol activation into cloud-droplets, and composition plays only a secondary role

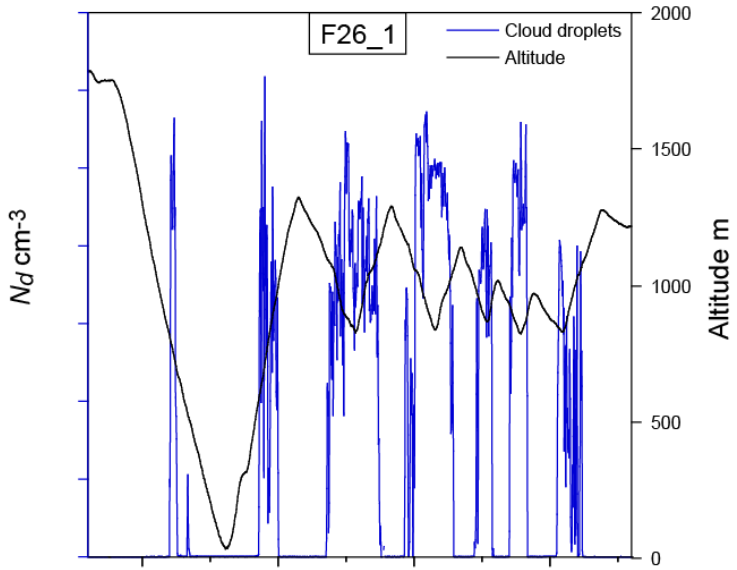
EXTRA SLIDES

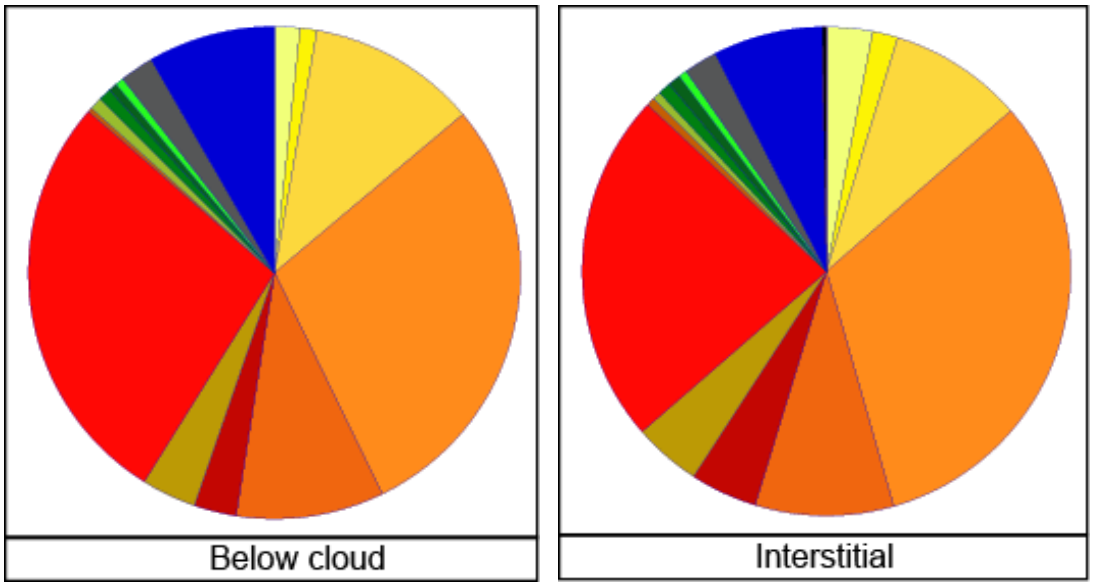
F26: Polluted Case.
Chemically-resolved Size Distributions

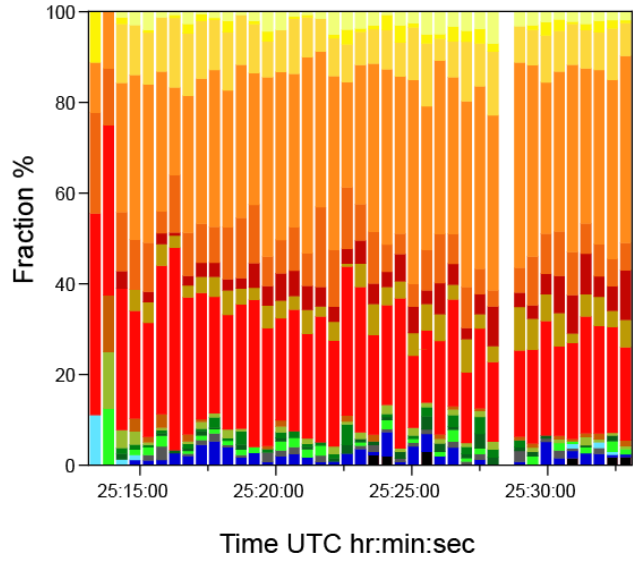
Color	Class	Density, g•cm^{-3}	Sulfate *WF*, %
	BB	1.32	0
	Low_sulf_BB_org	1.35	15
	BB_low_sulf	1.38	16
	BB_med_sulf	1.47	38
	BB_high_sulf	1.58	61
	Sulf_BB_org	1.45	40
	Soot_sulf_BB	-	-
	Sulf_org	1.47	50
	Org1	1.22	0
	Org2	1.24	0
	Org3	1.24	0
	Org4	1.24	0
	Pyridinium ion	1.5	0
	Soot_org	1.25	0
	SS	1.5	0
	Mineral dust	-	-



Step-by-Step Analysis of a Warm Cloud



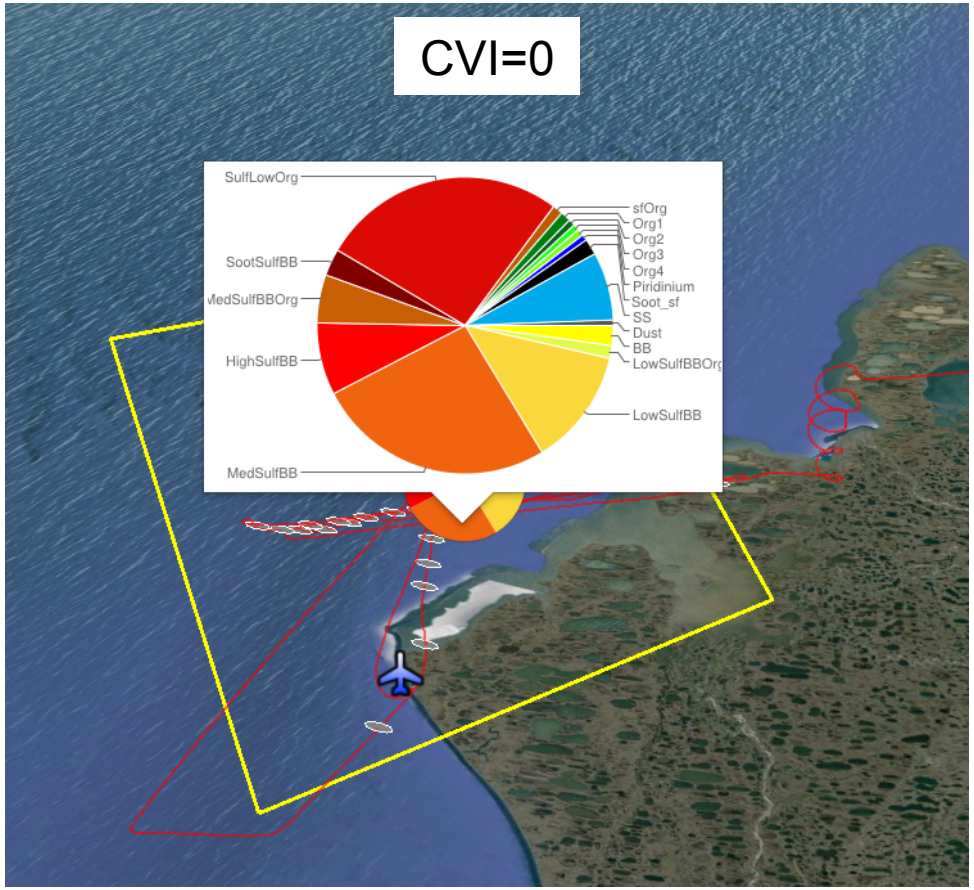




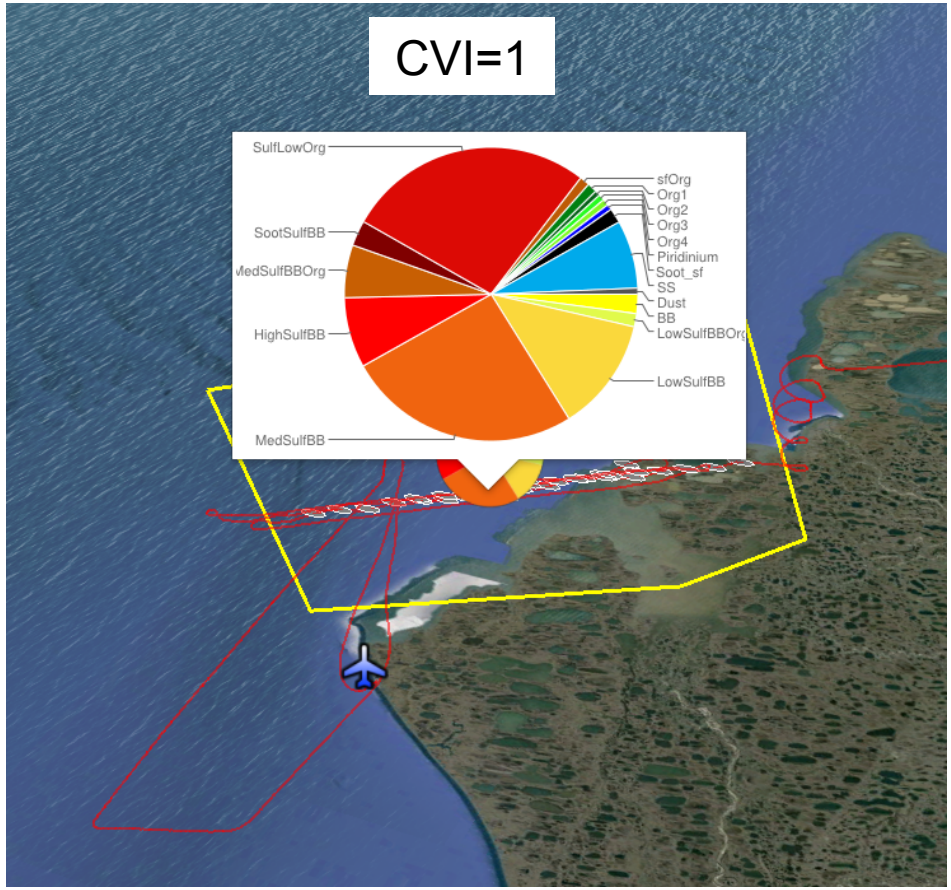
- Data were hand separated into in-cloud, above-cloud, and below-cloud segments
- Data show that the compositions of cloud droplet residuals, background aerosols, and interstitial particles are nearly the same
- Cloud activation probabilities are nearly composition-independent
- Particle size played a more important factor on aerosol CCN activity

Geo-Spacial View: Warm Cloud Characterization

Interstitial Particles

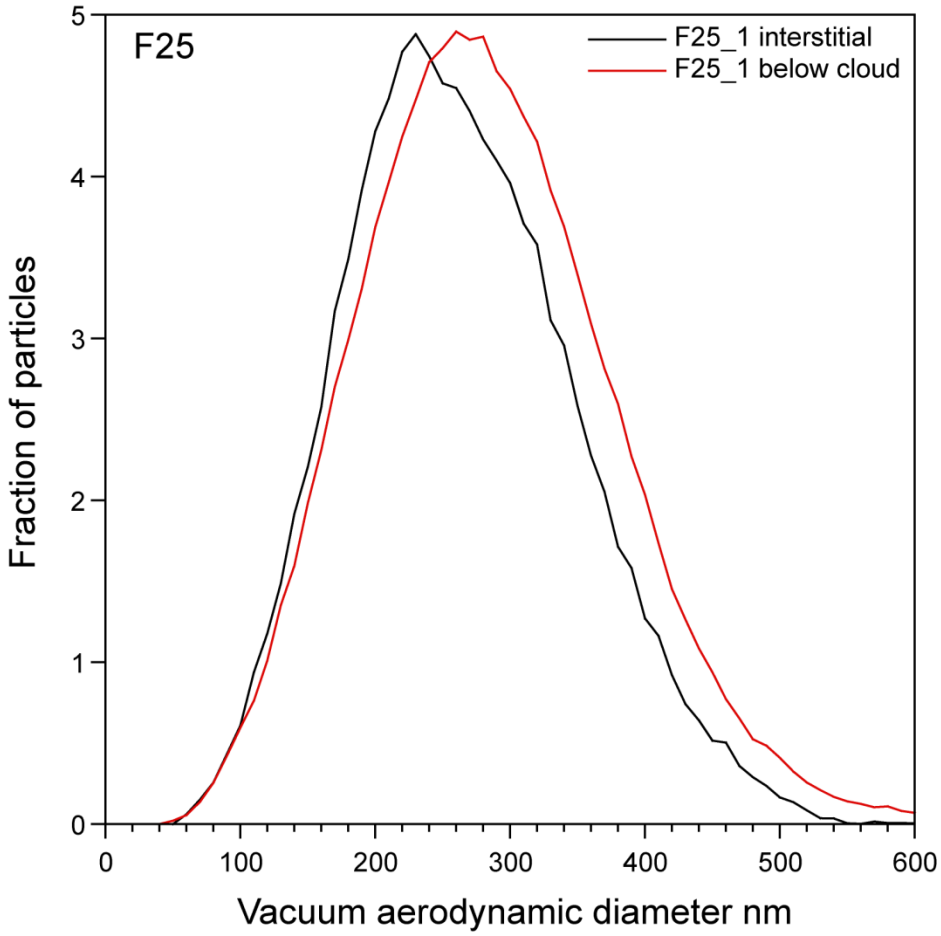


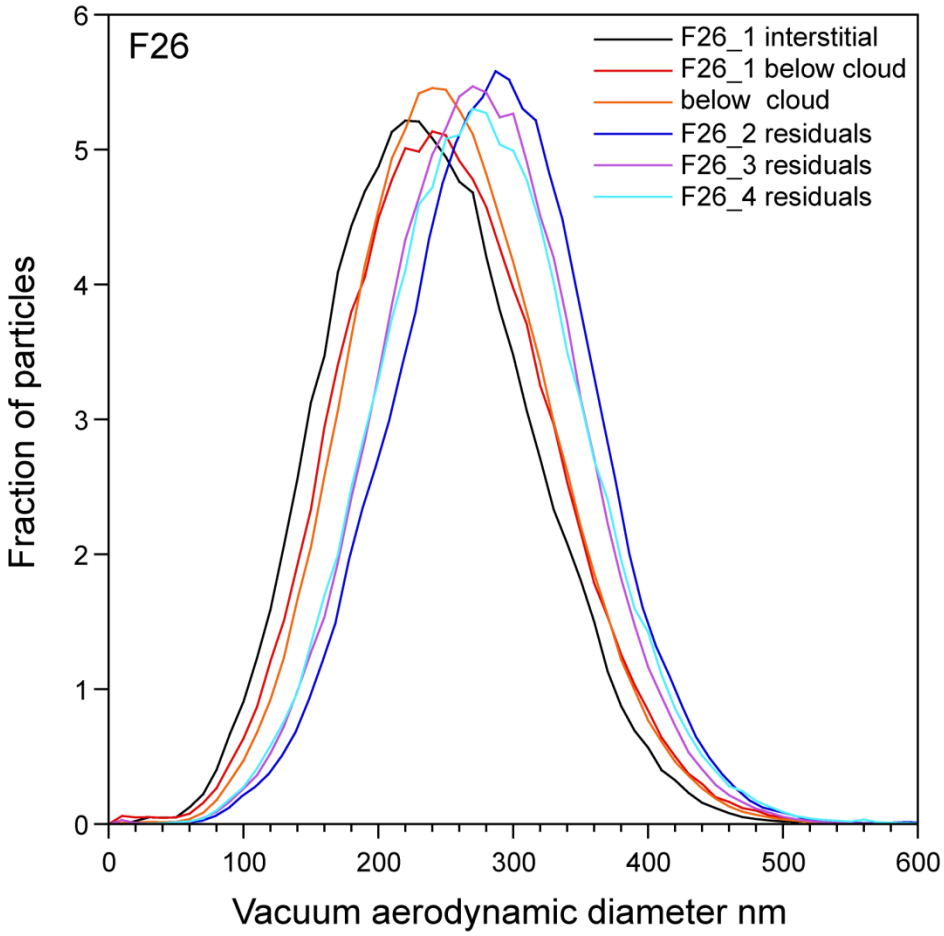
Cloud Residuals



- To view warm clouds we select Nd>10. To examine the properties of interstitial particles CVI=0, and cloud residuals CVI=1
- The data clearly show that the compositions of activated particles are virtually the same as interstitial particles

F26&26:Polluted Cases





- Comparison of vacuum aerodynamic size distributions of background aerosols below cloud, interstitial particles, and cloud droplet residuals
- The sizes of activated particles were slightly larger

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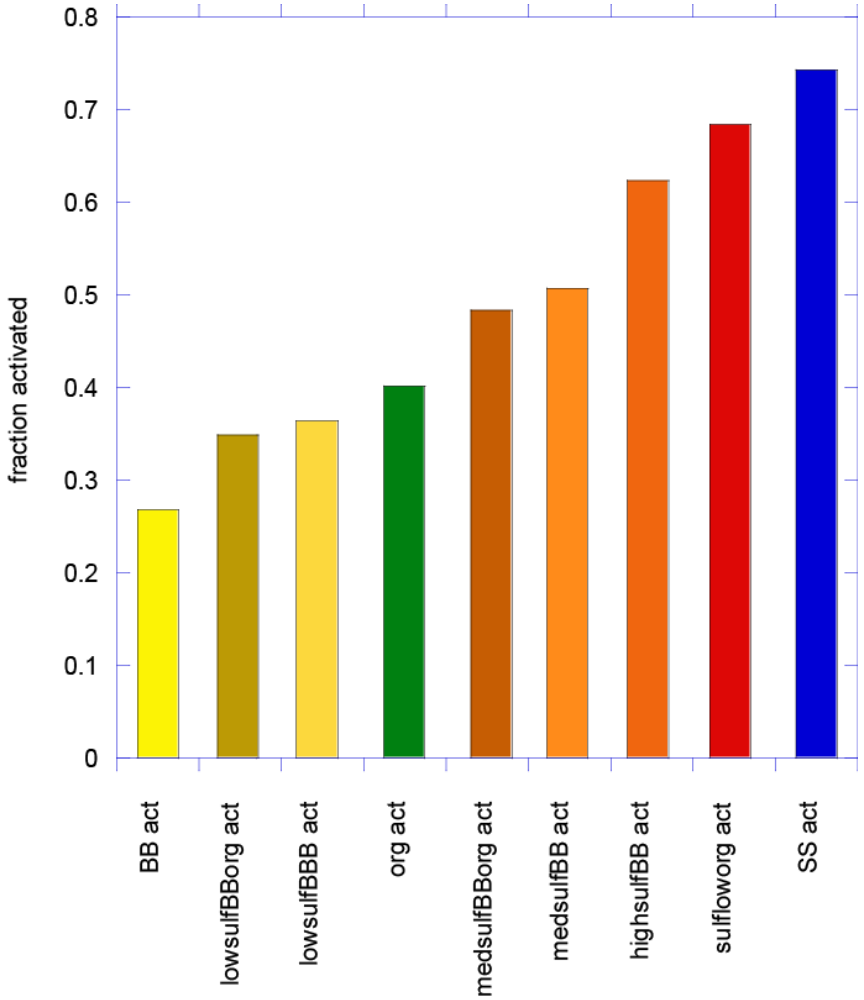
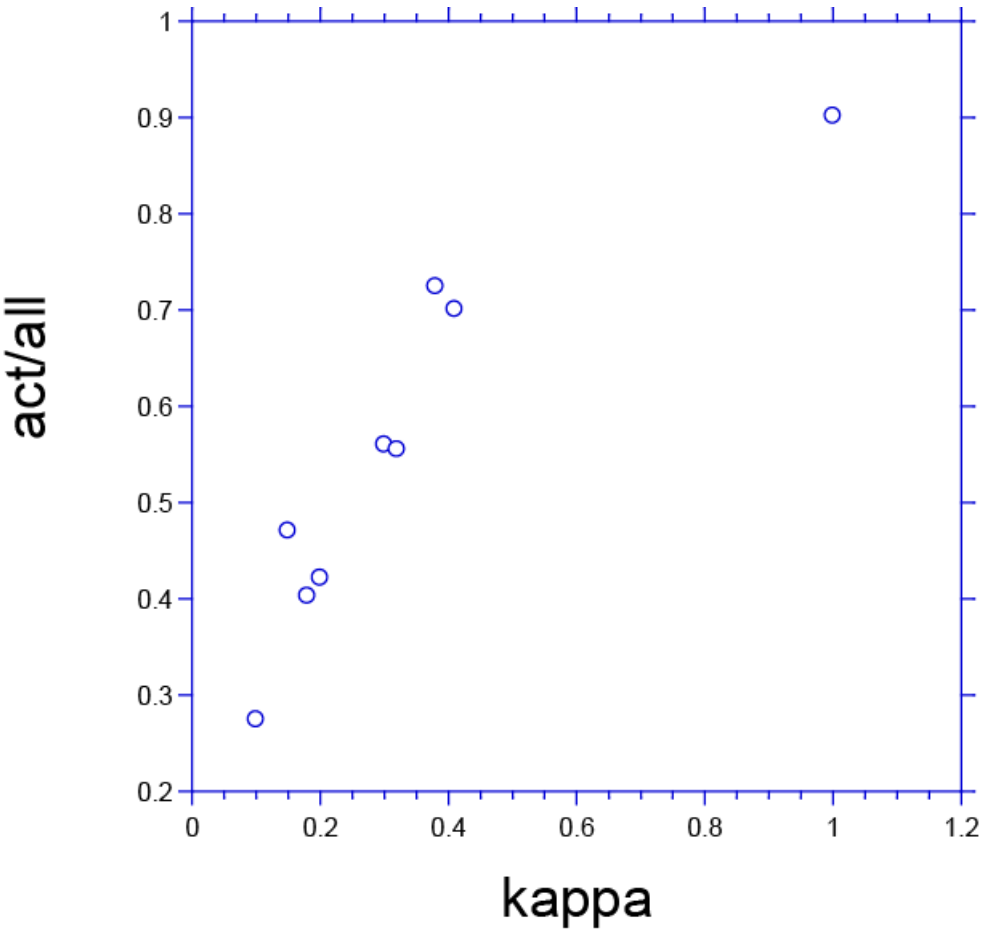
What do the models predict?





Model: Particles with larger kappa activate with higher probability

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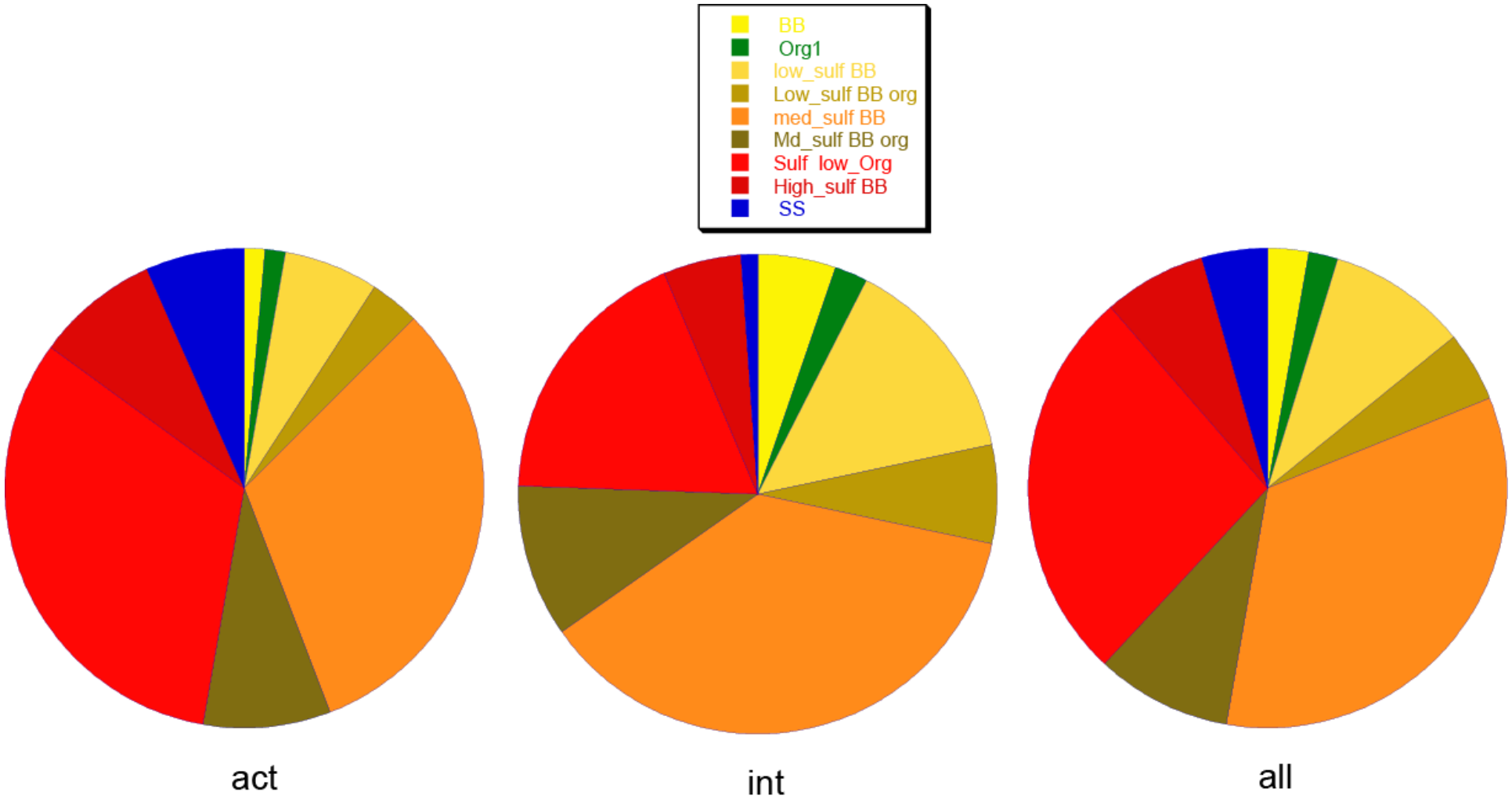

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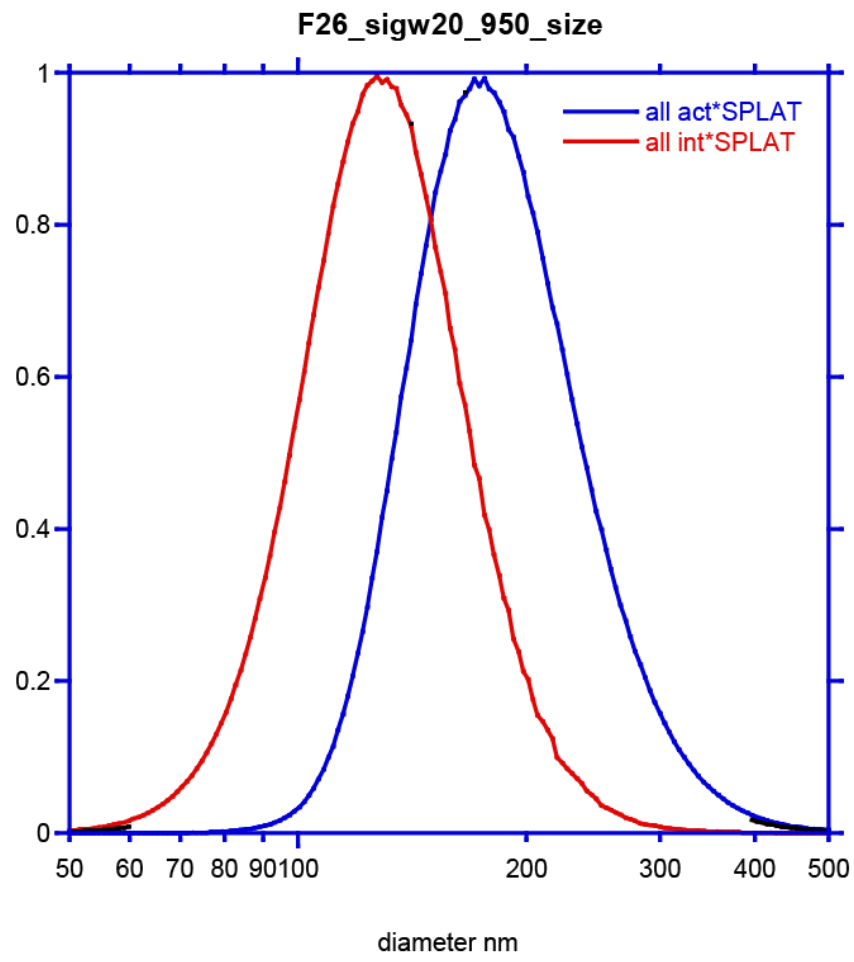
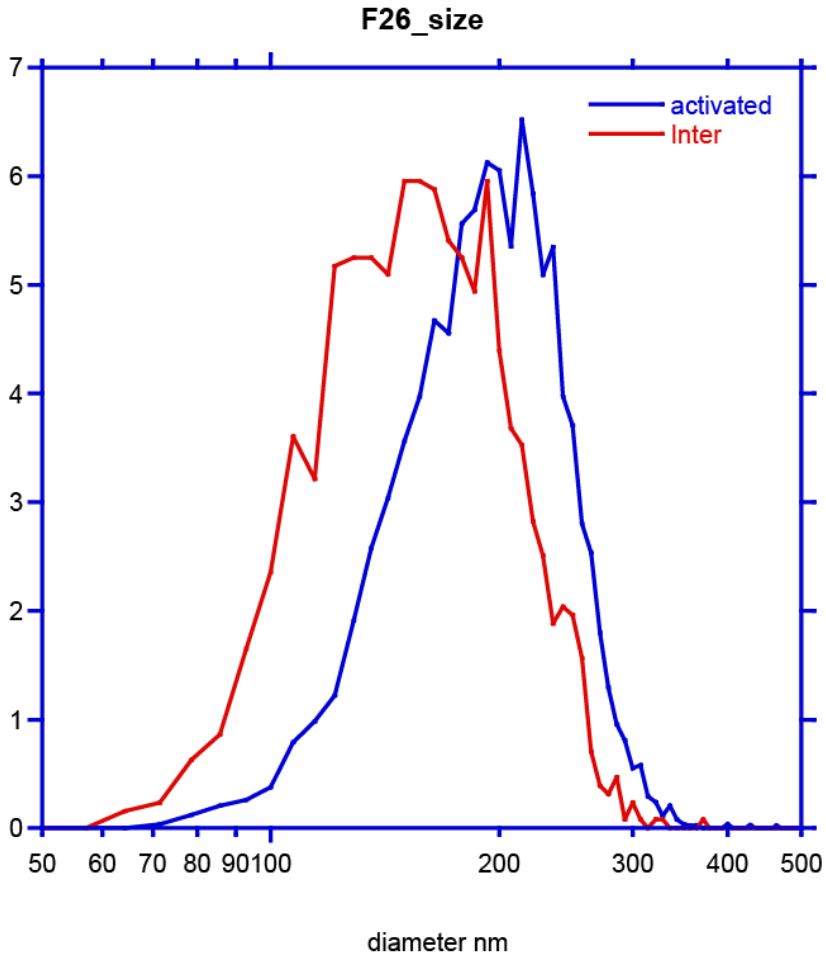
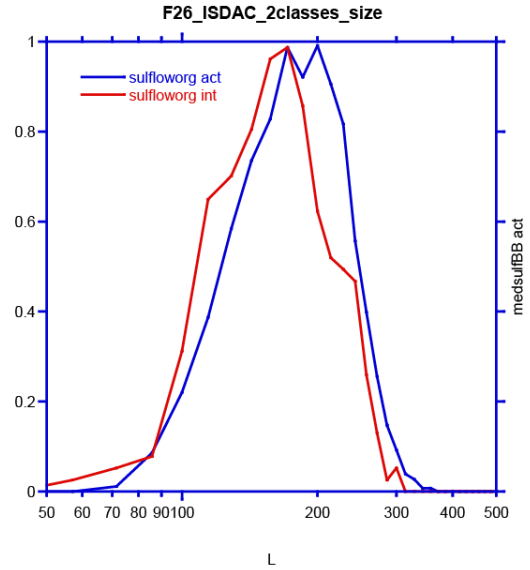
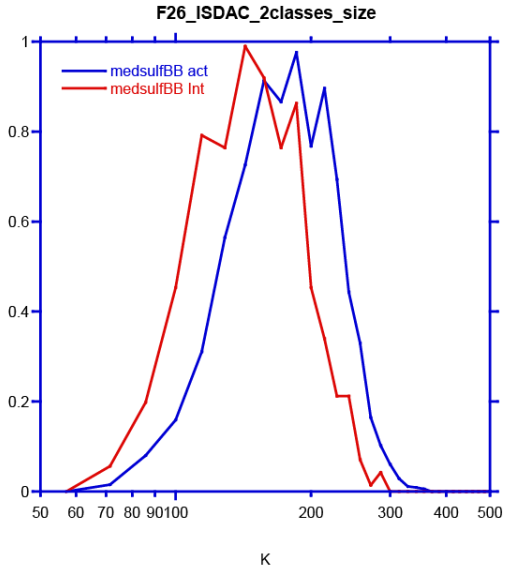


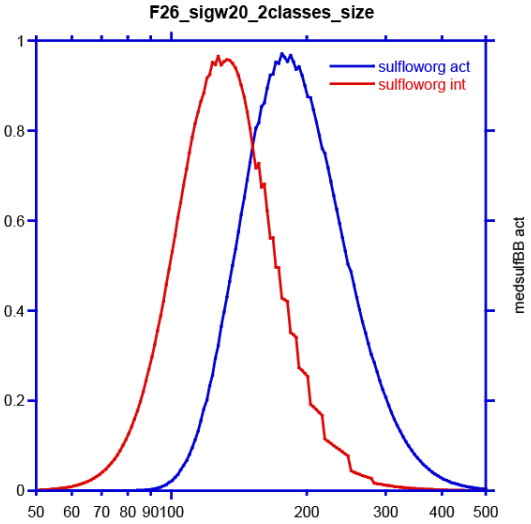


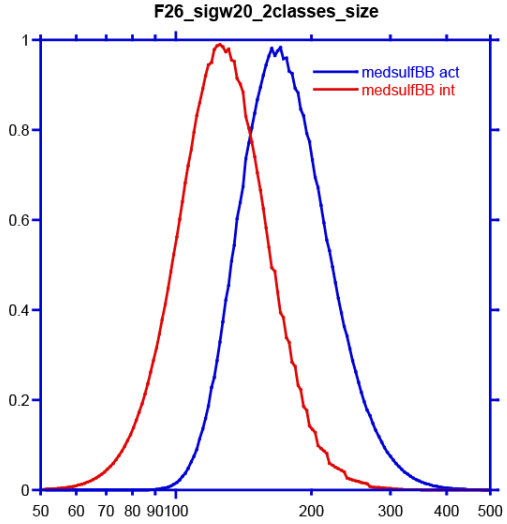
Both model and data show that larger particles activate with higher probability but model shows bigger differences.

What do the models predict?









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